The Affinity Constants of Amphoteric Electrolytes. II.—*Methyl Derivatives of Ortho- and Meta-aminobenzoic Acids.*

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(Communicated by Professor James Walker, F.R.S. Received May 21,—Read May 31, 1906.)

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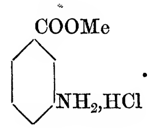
The investigation by Winkelblech* of various amphoteric electrolytes, and the subsequent application to his experimental figures of the theory of electrolytic dissociation and the law of mass action,† showed that the aminobenzoic acids exhibit their amphoteric character in a marked manner.

The following paper contains the results of an investigation of the methyl derivatives of ortho- and meta-aminobenzoic acids undertaken to ascertain the effect of successive introductions of a methyl group on the strength of these substances both as acids and as bases.

In order to obtain all the possible methyl derivatives of *m*-aminobenzoic acid and of anthranilic acid, it was found necessary to prepare several new substances and to revise some previous work. Since this portion of the research is only incidentally connected with the more physical part, it has been kept separate, and placed before the account of the physico-chemical measurements.

Hydrochloride of Methyl Ester of m-Aminobenzoic Acid, 

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The following method of preparation was found by trial to give good yields and was used throughout in the preparation of the esters and their hydrochlorides of both the ortho and meta series. Dry hydrogen chloride was passed through a boiling methyl alcoholic solution of the acid, which was contained in a flask fitted with an inverted condenser. On cooling the solution, it was found that the ester hydrochloride usually separated in crystals. In some instances crystals separated when the hydrogen chloride had passed for a few minutes, but this was due to the insolubility of the hydrochloride of the acid, and as the action progressed these crystals dissolved again.

When the hydrochloride of the ester proved to be soluble in alcohol, it was necessary to concentrate the solution before crystals would separate. The

* 'Zeit. f. physikal. Chem.,' vol. 36, p. 546, 1901.

† Walker, 'Roy. Soc. Proc.,' vol. 73, p. 155, and vol. 74, p. 271.

esters of the meta series formed much more slowly than those of the ortho series.

A convenient method of finding roughly how far the action had gone at any time was to take a small sample of the solution, boil off most of the hydrochloric acid, and then add some aqueous solution of sodium acetate, which caused the ester to separate as an oil. If the acid was insoluble, it also was precipitated.

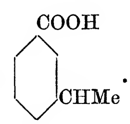
The hydrochloride of the methyl ester of *m*-aminobenzoic acid was made in this manner, and the action was found to be complete at the end of five hours. The crystals melted at 201° to 202°, with decomposition, and the melting point remained the same after two crystallisations from alcohol.

The amount of chloride in the recrystallised salt was estimated with the following result:—

0·1880 gramme of the salt contained 0·0389 gramme chlorine.

Found Cl	20·16 per cent.
Calculated for $C_8H_{10}O_2NCl$...........	20·46 ,,

The methyl ester of *m*-aminobenzoic acid separated as a fragrant oil when sodium acetate solution was added to a solution of the hydrochloride.

Monomethyl m-Aminobenzoic Acid, 

Equivalent quantities of *m*-aminobenzoic acid and methyl iodide were heated together in a sealed tube for about three hours at 100°, when it was found that combination had occurred, the resulting compound being the hydriodide of monomethyl *m*-aminobenzoic acid. This was crystallised from alcohol to remove any of the original acid, and appeared as a white crystalline substance, which melted with decomposition at 215°, and was soluble in hot water and alcohol, but much less so in the cold solvents. It did not crystallise well from water, as it underwent slight decomposition.

Estimation of the iodine present resulted as follows:—

0·2790 gramme of the substance contained 0·1253 gramme iodine.

Iodine found	44·9 per cent.
Calculated for $C_8H_{10}O_2NI$..............	45·3 ,,

The iodide dissolved readily in aqueous potash, and on addition of acetic acid, monomethyl *m*-aminobenzoic acid separated in small crystals, which, after crystallisation from water, were free from colour and melted at 147°. (The dimethyl acid melts at 151°.)

Estimation of the nitrogen by Kjeldahl's method gave the following results:—

0·143 gramme contained	0·0133	gramme of nitrogen	......	9·30 per cent.
0·147 „ „	0·0135	„ „	......	9·21 „

Calculated for $C_8H_9O_2NI$ ...... 9·30 per cent.

The substance was acid to litmus and to phenolphthalein.

0·1180 gramme neutralised with phenolphthalein as indicator 15·90 c.c. of 0·0500 N sodium hydroxide.

The combining weight calculated from these figures is 149, while that required for the formula $C_8H_9O_2N$ is 151.

Monomethyl *m*-aminobenzoic acid was found to be very soluble in alcohol, chloroform, and acetone when hot, but much less so in the cold. It was somewhat soluble in hot water and almost insoluble in cold water, ether, and ligroin; soluble in dilute mineral acids, but not in acetic acid.

The same substance was also prepared in the following manner, though the yield in this case was very small, on account of the number of operations. When an aqueous solution of the sodium salt of *m*-aminobenzoic acid was treated with an equimolecular amount of methyl sulphate, an orange-coloured acid substance was obtained which melted at about 145°, and retained the same melting point and appearance after crystallisation from several solvents.

Analyses showed that this was a mixture of the mono- and di-methyl acids, and variations in the method of preparation failed to give a pure product, whilst numerous attempts at separation by crystallisation were also unsuccessful.

The substitution of methyl iodide for methyl sulphate also yielded an orange-coloured substance, which, as far as it was examined, appeared to be the same mixture. The mixture was separated into its components by methylation with boiling methyl alcohol and dry hydrochloric acid, when the hydrochlorides of the methyl esters of the respective acids were formed. These were readily separated, as the hydrochloride of the methyl ester of monomethyl *m*-aminobenzoic acid is insoluble in cold alcohol, while that of the dimethyl acid is very soluble.

The two hydrochlorides obtained in this way possessed the same properties as those of the mono- and di-methyl acid esters made by other methods, as described below.

The monomethyl *m*-aminobenzoic acid was readily prepared from its ester hydrochloride by boiling with excess of aqueous caustic soda. The addition of acetic acid to the solution thus obtained precipitated the monomethyl

m-aminobenzoic acid, which does not form an acetate stable in aqueous solution. The acid so prepared was quite free from any pink colour.

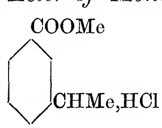
P. Griess* obtained a pink substance from α-benzcreatine, and described it as monomethyl *m*-aminobenzoic acid, but he gave neither analysis nor melting point.

The result of the work detailed above indicates that Griess' substance was probably a mixture, since the coloured substance which I obtained was proved to be a mixture, although both mono- and di-methyl *m*-aminobenzoic acids are free from colour when pure.

It was found that this pink colour could be produced by boiling a solution made from a mixture of the pure, colourless monomethyl and dimethyl acids, though on one occasion, for some unknown reason, the resulting colour was green. It is probable that the colour is due to oxidation.

From the failure to effect a separation of the mixture by crystallisation it was considered that the solubilities of the two acids in the various solvents tried must be very similar, and by experiment with the pure substances it was found that this was the case, the list of solubilities for the dimethyl acid being exactly the same as that given above for monomethyl *m*-aminobenzoic acids.

Hydrochloride of the Methyl Ester of Monomethyl m-Aminobenzoic Acid,



After treatment of a boiling methyl alcohol solution of monomethyl *m*-aminobenzoic acid with dry hydrogen chloride for four hours, crystals separated on cooling.

These were dried on tile, and found to melt at 75° to 78°. It must be mentioned that none of the melting points given for these hydrochlorides are true melting points, but are more or less definite decomposition temperatures. Estimation of the chloride present resulted as follows:—

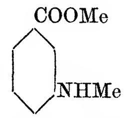
0·2010 gramme of the salt contained 0·0354 gramme chlorine.

Chlorine found...........................	17·61 per cent.
Calculated for $C_9H_{12}O_2NCl$...........	17·62 „

This hydrochloride was also prepared, as previously described, as a step in the preparation of monomethyl anthranilic acid. It can also be readily made from the ester by passing dry hydrochloric acid through an ethereal solution of

* 'Berichte,' vol. 8, p. 325.

the ester. However prepared, it is unstable, as it loses hydrochloric acid by simple exposure to the air.

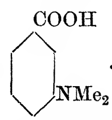
Methyl Ester of Monomethyl m-Aminobenzoic Acid, 

This substance was prepared by washing its hydrochloride with water, whereby all the hydrochloric acid was removed and the ester obtained as a white solid.

The methyl ester of monomethyl *m*-aminobenzoic acid was found to possess a faint pleasant odour, and was obtained in good crystals by slow evaporation of its ethereal solution. It was very soluble in ether, slightly soluble in alcohol, and extremely insoluble in water.

It melted at 72°, and thus differed in a marked manner from the esters of *m*-aminobenzoic acid and of the dimethyl acid, since both of these are oils.

The preparation of this ester and its hydrochloride in another way has been described under the preparation of monomethyl *m*-aminobenzoic acid.

Dimethyl m-Aminobenzoic Acid,  .

The orange-coloured mixture, obtained, as previously described (p. 105), by the action of methyl sulphate and caustic soda on *m*-aminobenzoic acid, was dissolved in just sufficient aqueous sodium hydroxide and again treated with methyl sulphate. The resulting crystalline precipitate was free from any pink colour, and proved to be dimethyl *m*-aminobenzoic acid. The yield was 30 per cent. of the calculated quantity, but could probably be much increased, since no attempt was made to find the best conditions. The separation of the dimethyl acid from the orange-coloured mixture by means of its methyl ester hydrochloride has already been described under monomethyl *m*-aminobenzoic acid. This method involved too many operations to give other than a very small yield.

P. Griess* prepared this acid from its methyl ester, which he obtained by melting *m*-benzbetaine; a quantity was prepared in this way according to his directions.

Another new method of preparing dimethyl *m*-aminobenzoic acid was discovered after sufficient for use had been obtained by the above three methods, but it appeared to be the easiest method of preparation.

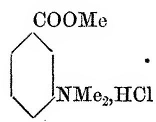
Some hydrochloride of *m*-benzbetaine was cautiously melted, when hydrochloric acid was evolved, and a yellow oil, the methyl ester of dimethyl

* 'Berichte,' vol. 6, p. 587.

m-aminobenzoic acid, remained behind. From the ester, the acid was readily prepared by boiling for a few minutes with potash solution, and then adding acetic acid, when the dimethyl acid separated in small crystals. As the hydriodide of *m*-benzbetaine proved to be one of the easiest derivatives to prepare, the same action was then tried with it. Like the hydrochloride, it also yielded the ester of the dimethyl acid on heating.

The samples obtained by the above methods were each found to agree with Griess' description.

Hydrochloride of the Methyl Ester of Dimethyl m-Aminobenzoic Acid,



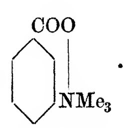
Some *m*-benzbetaine was placed in a tube in a metal bath and the tube exhausted. The temperature was kept at 150°, until all the water from the deliquescent betaine was removed, and was then raised for 15 minutes to 220°, at which temperature Griess showed* that *m*-benzbetaine changes into the isomeric methyl ester of dimethyl *m*-aminobenzoic acid.

The ester was dissolved in ether, and dry hydrochloric acid was passed through the solution. The resulting crystalline precipitate, after several washings with ether, was dried on tile. This hydrochloride was found to be a pure white crystalline salt, which melted at 175° to 177°, and contained the following amount of chlorine:—

0·1805 gramme contained 0·0295 gramme of chlorine.

Chlorine found..........................	16·04 per cent.
Calculated for $C_{10}H_{14}O_2NCl$	16·45 „

m-Benzbetaine,



m-Aminobenzoic acid was dissolved in 50-per-cent. methyl alcohol and to the solution were added three equivalents of methyl iodide, together with one equivalent of potassium hydroxide. The solution was then allowed to stand for several days, with addition of more potash whenever it was found to have become acid, until three equivalents of potash had been used.

Thus far the method used was similar to that employed to obtain *p*-benzbetaine, by Michael and Wing,† but the subsequent treatment was different.

* *Loc. cit.*

† 'Amer. Chem. Journ.,' vol. 7, pp. 196—7.

Michael and Wing first evaporated the solution to dryness, and then went through several operations to remove the potassium iodide, after which the betaine was precipitated as the hydriodide by addition of hydriodic acid.

The method I adopted was to concentrate the solution sufficiently to remove most of the alcohol, and then add a little acetic acid to precipitate any mono- or di-methyl acid present. After filtration, hydrochloric acid was added, whereby all the *m*-benzbetaine present was precipitated as hydriodide, since the solution contained plenty of potassium iodide.

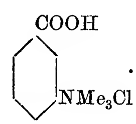
The *m*-benzbetaine hydriodide was found to be almost entirely free from chloride, methiodide and periodide, and was readily purified by crystallisation from water. It melted at 180°, and estimation of the iodine present gave the following result :—

0·3925 gramme of the iodide contained 0·1605 gramme of iodine.

Iodine found	40·90 per cent.
Calculated for $C_{10}H_{14}O_2NI$	41·36 „

m-Benzbetaine was prepared from the hydriodide by treatment with moist silver oxide or lead hydroxide, and was purified by several crystallisations from alcohol. It was very deliquescent, and at 215° to 220° was transformed into the methyl ester of dimethyl *m*-aminobenzoic acid.*

o-Benzbetaine was successfully obtained by the use of the same process, so it may be of general applicability in the preparation of benzbetaines.

Hydrochloride of m-Benzbetaine, 

This was prepared by mixing the betaine with concentrated hydrochloric acid. The salt is almost insoluble in concentrated hydrochloric acid and only slightly soluble in water. It was found to be white and not deliquescent; it melted at 192°, and contained the following amount of chlorine :—

0·1940 gramme contained 0·0298 gramme of chlorine.

Chlorine found.....................	15·35 per cent.
Calculated for $C_{10}H_{14}O_2NCl$ ...	16·45 „

The hydrochloride was recrystallised from alcohol, and the chlorine again estimated :—

0·1880 gramme contained 0·0285 gramme of chlorine.

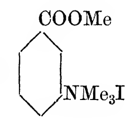
Chlorine found.............. 15·18 per cent.

* Griess, *loc. cit.*

The hydrochloride was then suspended in alcohol and dry hydrochloric acid led through. The crystals were then filtered off, and dried on a tile, not in a desiccator :—

0·198 gramme contained 0·0324 gramme of chlorine.
Chlorine found.............. 16·36 per cent.

This sample was used at once in a catalysis experiment, as it contained the right proportion of chlorine.

Methiodide of the Methyl Ester of Dimethyl m-Aminobenzoic Acid, 

This substance was readily obtained by the action of methyl iodide on the methyl ester of dimethyl *m*-aminobenzoic acid, as described by Willstätter and Kahn.* These authors drew attention in their paper to the ease with which betaines of this class yielded, by internal rearrangement, the isomeric methyl ester of the dimethyl acid, and showed this property to be well marked in the case of *m*-benzbetaine. In this connection the following new mode of obtaining the quaternary iodide is of some interest, though it offers no advantages as a method of preparation :—

Some dry *m*-benzbetaine was kept in a closed tube with methyl iodide at 30° to 40° for 24 hours, when it was found that most of the betaine had been used up with formation of the quaternary iodide. That this reaction is simply a combination of the betaine with methyl iodide does not seem probable. It is more probable that the change of *m*-benzbetaine into the ester proceeds even at low temperatures, but reaches an equilibrium, unless the ester is removed as it is formed. In this case we know that methyl iodide combines quickly and readily with the methyl ester of *m*-aminobenzoic acid. The ester would thus be removed as it was produced, and the reaction would therefore proceed steadily to completion. The application of this hypothesis to the similar ortho compounds would require the reaction between *o*-benzbetaine and methyl iodide to proceed much more slowly, as the interaction of the methyl ester of dimethyl anthranilic acid and methyl iodide is known to be very slow. By experiment it was found that only a small yield of the quaternary ortho iodide was obtained when a mixture of methyl iodide and *o*-benzbetaine had been kept in a warm place for two weeks.

* 'Berichte,' p. 411, 1904.

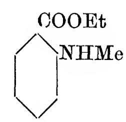
Preparation of the Ortho-aminobenzoic Acid Series.

All the methyl derivatives of this series have been described, and the samples used were prepared mainly by the methods of Willstätter and Kahn.*

There is a slight ambiguity in a passage of their paper which conveys the impression that the compound which they obtained by the action of methyl sulphate on anthranilic acid was the methyl ester of monomethyl-anthranilic acid instead of the acid itself. It may be mentioned that in an abstract of their paper† it is stated that they obtained the methyl ester in this way and not the acid. To prevent the possibility of any mistake, the substance, prepared according to their directions, was analysed, with the following result:—

0·2120 gramme of the substance gave on combustion 0·1165 gramme of water and 0·4935 gramme of carbon dioxide.

Found	C = 63·49,	H = 6·10
Calculated for monomethyl-anthranilic acid	C = 63·57,	H = 5·96

Ethyl Ester of Monomethyl-anthranilic Acid, 

This was prepared from monomethyl-anthranilic acid by the action of boiling ethyl alcohol and hydrogen chloride for 10 hours. The solution was evaporated almost to dryness, and then excess of dilute caustic soda was added, whereby the ester separated as an oil, which was removed by extraction with ether. The ethereal solution was washed with dilute alkali, dilute hydrochloric acid, and then several times with water, after which the ether was evaporated.

The ethyl ester of monomethyl-anthranilic acid was found to be a colourless oil with a pleasant odour of jasmine. It was solid below 18° to 20°, and, therefore, closely resembled the methyl ester in both odour and melting point. It was somewhat soluble in alcohol, freely soluble in ether, and so extremely insoluble in water and acids that it was not found possible to determine its strength as a base.

The hydrochloride was prepared as a white crystalline salt by passing dry hydrogen chloride into a solution of the ester. It was soluble in alcohol, insoluble in ether, and mixing it with water caused an instantaneous

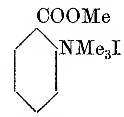
* 'Berichte,' p. 401, 1904.

† 'Chem. Soc. Journ.,' 86, I, p. 235, 1904.

separation of the ester from the hydrochloric acid. Analysis of the amount of chlorine present gave this result :—

0·1890 gramme of the hydrochloride contained 0·0312 gramme of chlorine.

Found chlorine	16·50.
Calculated for $C_{10}H_{14}O_2NCl$	16·45.

Methiodide of the Methyl Ester of Dimethyl-anthranilic Acid, 

This compound was prepared in the manner recommended by Willstätter and Kahn,* namely, by the interaction of methyl iodide and the methyl ester of dimethyl-anthranilic acid, and it was found that the yield became almost theoretical if the mixture was kept for many days at about 40°.

The above authors state that this combination does not occur in ethereal solution, but this is not strictly correct, as the action does take place, though with extreme slowness. Ether, however, is a poor solvent for the purpose, and it was found that if alcohol or acetone were employed, the rate of reaction approximated to that observed in the absence of any solvent. However, as a method of preparation it is best to use no solvent.

Determination of the Acid and Basic Constants.

Except where it is specifically stated that some other temperature was employed, the experiments detailed in the following pages were performed in a thermostat, which was kept at 25° to within one-tenth of a degree.

Basic Constants.—There are a number of methods available for the determination of the strength of weak bases, and of these the methyl acetate catalysis method was found to be the most generally applicable. The comparison method, details of which may be found in the paper of Walker and Wood,† was employed as being the most accurate and, as the figures below will show, these amphoteric electrolytes gave as good results as those obtainable with ordinary electrolytes.

As a general rule the hydrochloride was used, but in a few cases the hydriodide was more readily prepared in a state of purity and was therefore substituted for the chloride. One might naturally expect the hydrolysis of a chloride and of an iodide to be equal, but as there was no experimental evidence as to the action of hydriodic acid and iodides on methyl acetate a few experiments were tried.

* *Loc. cit.*

† 'Chem. Soc. Journ.,' vol. 83, p. 484.

Solutions were prepared, one of which was N/200 for hydrochloric acid and N/10 for potassium chloride, while the other was N/200 for hydriodic acid and N/10 for potassium iodide. The experiments were performed in duplicate, and the constant found for the chloride solution was 0·00080 as against 0·00053 for the iodide. Both acids were standardised in the same manner and against the same soda solution. To eliminate any error in determining the strength of the acids, the following experiments were next performed:—

Solution A was made from 10 c.c. of N/10 hydrochloric acid, 1·5 grammes of potassium chloride, and 10 c.c. of water, and was, therefore, N/20 for acid and N for total chloride.

c found = 0·000158.

Solution B was made from 10 c.c. of N/10 hydrochloric acid, 2·38 grammes of potassium bromide, and 10 c.c. of water, and was, therefore, N/20 for acid and N for total bromide contents.

c found = 0·000160.

Solution C was made from 10 c.c. of N/10 hydrochloric acid, 3·3 grammes of potassium iodide, and 10 c.c. of water, and was, therefore, N/20 for acid and N for total iodide contents.

c found = 0·000140.

Since an equal quantity of the same acid was used in all cases, the difference can only be due to the difference between chloride and iodide. It will be noticed that the bromide and chloride agree, and that the error arising from the use of an iodide is that too low a value is obtained for the hydrolysis, and consequently too high a value for k_b/K. The cause is most probably oxidation of the hydriodic acid, since the solution, which at the start was almost colourless, always darkened during the experiment.

Other methods for determining the basic constant were also tried, but were mostly unsatisfactory on account of the readiness with which the substances oxidise in solution.

Acid Constants.—In some cases an attempt was made to determine the acid dissociation constant by direct measurement of the hydrion concentration by the interesting new method of Bredig and Fraenkel,* who have found that extremely small concentrations of hydrion can be measured by the rate at which the catalysis of diazo-acetic ester occurs. Details of the method as applied in this research will be found under anthranilic acid (*o*-amino-benzoic acid).

The acid dissociation constants for the stronger acids were obtained by

* 'Zeit. Elektrochem.,' vol. 2, p. 525, 1905.

calculation from the conductivities by Walker's method. As most of these substances possess a tendency to oxidise in solution, the conductivity was always determined in a cell with unplatinised electrodes, but as they are all feeble electrolytes, this did not diminish the accuracy of the readings.

The water used for the conductivities was prepared as recommended by Walker and Cormack,* and none was used with a conductivity greater than $1{\cdot}5 \times 10^{-6}$ at 25°.

The sodium hydroxide used in the preparation of the sodium salts was made by exposing metallic sodium to a wet atmosphere in a vessel protected from the atmosphere until it was completely hydrated, and the hydroxide was then dissolved in pure "conductivity" water. Platinised electrodes were, of course, available for the sodium salts.

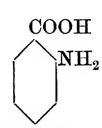
Saponification of Methyl Acetate (Shields' Method).—Where the conductivity of any substance proved too small to be of any use, the strength of the acid was found by the rate at which the sodium salt saponified a methyl-acetate solution.† Several attempts were made to prepare the sodium salts in the solid state to insure that exactly equivalent proportions of acid and base were present. Addition of alcohol and ether precipitated the sodium salt from a strong aqueous solution, but in such a gelatinous form that it was not capable of purification.

Consequently, all the sodium salts mentioned in this paper were prepared by solution of a weighed quantity of acid in a standard solution of pure sodium hydroxide. For a methyl-acetate saponification experiment so much of the acid, sodium hydroxide, and methyl-acetate solutions were mixed as to make the solution the same strength for all constituents. The equation for the reaction is then,

$$kc = \frac{1}{t}\left(\frac{E}{E-x} - 1 - \log_e \frac{E}{E-x}\right),$$

where E is the initial titre, and x the amount changed in any time t. The constant for sodium hydroxide k in the same units at 25° is about $10{\cdot}5$.

From c we obtain k_a by means of the relation $k_a = \dfrac{1{\cdot}2 \times 10^{-14}}{c}$

Anthranilic Acid, 

Basic Constant and Dilution Law.—It has been assumed that the dilution law for simple bases‡ holds true also for amphoteric electrolytes, but there

* 'Chem. Soc. Journ.,' vol. 77, p. 8, 1900.
† Shields, 'Phil. Mag.,' vol. 35, p. 365, 1893.
‡ Arrhenius, 'Zeit. physikal. Chem.,' vol. 5, p. 16, 1890.

has been no experimental justification by the catalysis method for this assumption. The hydrolysis of the hydrochloride of anthranilic acid was therefore determined at several dilutions, by the comparative methyl acetate catalysis method of Walker and Wood.*

If the dilution law is true, then the ratio k_b/K should be the same, whatever the dilution at which the experiment is performed, since by this law the following formula holds true for all dilutions:—

$$\frac{(\text{free acid}) \times (\text{free base})}{(\text{salt})} = \frac{\mathrm{K}}{k_b}.$$

The results for anthranilic acid hydrochloride were as follows, x being the amount hydrolysed:—

v.	x found.	x calculated for $k_b/\mathrm{K} = 110$.
2	0·122	0·126
5	0·187	0·191
10	0·255	0·260
20	0·350	0·345
50	0·498	0·484

It will be seen that the dilution law does not hold strictly true, but the error introduced by calculation from one dilution to another is only a minor one, if the two dilutions be reasonably near one another.

Hydrion Concentration.—One of the most striking facts in connection with amphoteric electrolytes is that the conductivity does not give a direct estimate of the hydrion concentration.

Bredig and Fraenkel† have recently devised a simple method for the estimation of hydrion in small concentrations by the catalysis of diazo-acetic ester, the rate of the reaction, which is monomolecular, being followed by observing the amount of nitrogen evolved. The experiments with this method which are given in this paper were all performed in a thermostat at 25°. The same volumes were used in all cases to render the experiments comparable, namely 20 c.c. of the solution containing the hydrion, 0·1 c.c. of diazo-acetic ester, and 2 c.c. of ethyl-alcohol. The diazo-acetic ester was also weighed as a check. No reading was taken for the first few minutes after mixing.

* *Loc. cit.*

† *Loc. cit.*

Anthranilic Acid. $v = 32$.

t.	Reading.	x.	A$-x$.	c.
0	2·80	—	22·00	—
10	4·40	1·60	20·40	0·00328
20	5·83	3·03	18·97	321
42	8·50	5·70	16·30	310
82	12·93	10·13	11·87	327
141	17·40	14·60	7·40	336
232	21·15	18·35	3·65	336
∞	24·80	—	—	—
		Mean		0·00325

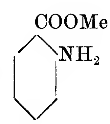
As a standard of comparison, acetic and benzoic acids were investigated under the same conditions.

N/64 benzoic acid, which has a hydrion concentration of $93 \cdot 7 \times 10^{-5}$, gave a constant of 0·0101 in the same units.

N/10 acetic acid with a hydrion concentration of 126×10^{-5} gave a constant of 0·0166.

The hydrion concentration of N/32 anthranilic acid, if the benzoic acid be taken as the standard of comparison, $= 30 \times 10^{-5}$, while if the acetic acid be used as the standard it is 25×10^{-5}.

Walker* has calculated the hydrion concentration in anthranilic acid solutions from the experimental data of Winkelblech, and according to his equations it should, in N/32 solution, be 27×10^{-5}, whilst a simple acid of similar conductivity would have a hydrion concentration of 47×10^{-5}. The result is thus in excellent accord with Walker's calculation.

Methyl Ester of Anthranilic Acid, 

For the determination of the strength of the ester as a base the twice crystallised hydrochloride was used. This was made from anthranilic acid,† and melted at 135°. Estimation of the chlorine resulted as follows:—

0·1880 gramme contained 0·0353 gramme of chlorine.

Found chlorine	18·75
Calculated for $C_8H_{10}O_2NCl$......	18·90

* *Loc. cit.*

† Erdmann and Erdmann, 'Berichte,' vol. 32, p. 1215.

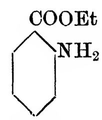
Methyl Acetate Catalysis.—0·3755 gramme of hydrochloride of methyl ester of anthranilic acid in 20 c.c. of water.

$v = 10$, $A = 13·61$.

t.	Titre.	x.	$A-x$.	c.
0	3·10	—	13·61	—
2770	7·93	4·83	8·78	0·000687
5490	11·00	7·90	5·71	687
7000	12·25	9·15	4·46	692
7600	12·77	9·67	3·94	707
8370	13·15	10·05	3·56	696
			Mean	0·000694

Comparison Solution.—N/10 for total chloride, N/40 for free HCl, $c = 0·000749$, hydrolysis in N/10 solution = 23·2 per cent.

$k_b/K = 143$.

Ethyl Ester of Anthranilic Acid,  .

The hydrochloride of this ester was prepared like the similar compounds and crystallised from alcohol. The melting point was 168°, and analysis of the amount of chlorine gave the following result:—

0·1735 gramme of the hydrochloride contained 0·0304 gramme of chlorine.

Chlorine found.......................... 17·50 per cent.
Calculated for $C_9H_{12}O_2NCl$........... 17·58 „

Methyl Acetate Catalysis.—The hydrochloride of this ester is so much hydrolysed in solution, and the ester itself so insoluble, that it was not found possible to work with a solution stronger than N/100, and the satisfactory estimate obtained at this dilution shows the wide applicability of the method.

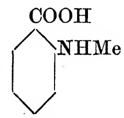
0·0410 gramme of the hydrochloride of the ethyl ester of anthranilic acid in 20 c.c. water.

$v = 100$. $A = 27·10$.

t.	Titre.	x.	$A-x$.	c.
0	0·23	—	27·10	—
370	2·50	2·27	24·83	0·0001027
625	3·85	3·62	23·48	0999
710	4·33	4·10	23·00	1004
870	5·16	4·93	22·17	1018
1110	6·40	6·17	20·93	1012
1385	7·75	7·52	19·58	1017
			Mean	0·0001013

Comparison Solution.—N/100 for chloride, N/200 for free hydrochloric acid, hydrolysis in N/100 solution = 57·8.

$$k_b/\mathrm{K} = 126.$$

Monomethyl-anthranilic Acid, 

Two samples of this were prepared by different methods:—

(A) A quantitative yield was obtained by the use of methyl sulphate (Willstätter and Kahn). Reference has already been made to this method and an analysis given of the sample, which was crystallised from alcohol and then three times from water before use in the following experiments.

(B) Another sample, which was used only for a conductivity determination, was made by the action of methyl iodide and potash on anthranilic acid.* Before use the sample was crystallised six times from water.

Basic Constant.—Monomethyl-anthranilic acid is so insoluble that it was found necessary in the methyl acetate catalysis experiments to take more hydrochloric acid than corresponded to the amount of base, and to use supersaturated solutions, in order that the experiments might not be unduly prolonged.

As this diminishes the accuracy of the method, two experiments were performed with different ratios of acid to base.

Methyl Acetate Catalysis.—I. 0·1510 gramme of monomethyl-anthranilic acid in 50 c.c. of N/20 hydrochloric acid.

v for base = 50. v for acid = 20. A = 19·60.

t.	Titre.	x.	A − x.	c.
0	2·90	—	19·60	—
2965	12·30	9·40	10·20	0·0000957
3223	12·90	10·00	9·60	962
3790	14·03	11·13	8·47	962
4270	14·90	12·00	7·60	963
5360	16·50	13·60	6·00	959
6815	18·17	15·27	4·33	962
		Mean	....	0·0000961

Comparison Solution.—N/20 for total chloride, 0·036 N for free hydrochloric acid, mean c = 0·0000980.

$$k_b/\mathrm{K} = 79·5.$$

* Schultz and Flachsländer, abstract in 'Chemisches Centralblatt,' (2), 448, 1902.

II. A solution was made from 0·1510 gramme monomethyl-anthranilic acid and 15 c.c. N/10 hydrochloric acid, diluted to 110 c.c. with water. These irregular quantities were taken because they were the smallest amounts of acid and water in which the base would remain dissolved, when the solution was cooled from the high temperature used to obtain the solution.

v for base = 110. v for acid = 73·3. A = 19·70.

t.	Titre.	x.	A − x.	c.
0	1·00	—	19·70	—
5,460	6·70	5·70	14·00	0·0000272
6,835	7·87	6·87	12·83	273
8,300	9·05	8·05	11·65	275
8,730	9·36	8·36	11·34	275
9,750	10·14	9·14	10·56	278
10,360	10·57	9·57	10·13	278
			Mean	0·0000275

Comparison Solution.—0·016 N for total chloride, N/100 for free hydrochloric acid, mean c = 0·0000290.

The method of calculation used to find k_b/K in an experiment such as the above is as follows:—

Base taken	0·00906 N	Free acid = $\frac{275}{290} \times 0{\cdot}1$ ...	0·00948 N
Total acid taken	0·01364 N	Salt present	0·00416 N
		Free base present	0·00493 N

$$\frac{\text{Free acid} \times \text{free base}}{\text{salt}} = \frac{0{\cdot}00943 \times 0{\cdot}00493}{0{\cdot}00416} = 0{\cdot}0132 = \frac{K}{k_b}.$$

$$k_b/K = 75{\cdot}7.$$

Mean of I and II .... $k_b/K = 77{\cdot}6$.

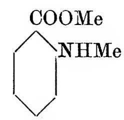
Acid Constant.—Monomethyl-anthranilic acid possesses marked acid properties, as was shown by the fact that it could be accurately titrated against soda with phenolphthalein as indicator. Its strength as an acid was found from the conductivity determinations, which were done on solutions prepared separately by dissolving weighed quantities of the acid in 1 litre of water in a bottle of "Resistenzglas."

Sample.	v.	μ.	100 m.	100 k.
A	775	21·1	5·74	0·000451
A	1025	24·9	6·62	0·000458
A	1510	31·1	8·16	0·000480
B	1510	30·4		

The conductivity of the sodium salt of monomethyl-anthranilic acid was also determined.

v	32	1024
μ	68·8	78·4

80 was taken as the value at infinite dilution, and this gave for monomethyl-anthranilic acid, $\mu_\infty = 376$. Turning to the acid constant to be deduced from these figures, examination of the tables given in Walker's paper show that where k_b is small, α and a are practically identical at high dilutions, such as were employed here. The value of k_a for monomethyl-anthranilic acid may be taken then as $0{\cdot}46 \times 10^{-5}$.

Methyl Ester of Monomethyl-anthranilic Acid, 

Basic Constant.—The hydrochloride of monomethyl-anthranilic acid was prepared from the acid by the combined action of methyl alcohol and hydrogen chloride. It was a salt which crystallised from alcohol in fine, colourless needles, was very soluble in water, insoluble in ether, and melted at 218°.

The sample used was crystallised twice from alcohol and analysed for chlorine.

0·2010 gramme contained 0·0353 gramme of chlorine.

Chlorine found.....................	17·56 per cent.
Calculated for $C_9H_{12}O_2NCl$......	17·62 ,,

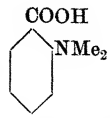
Methyl Acetate Catalysis.—0·8060 gramme of the hydrochloride of methyl ester of monomethyl-anthranilic acid was dissolved in 20 c.c. of water.

$v = 5.$ A = 17·10.

t.	Titre.	*x.*	A−*x.*	*c.*
0	5·35	—	17·10	—
37·5	7·25	1·90	15·20	0·00137
85	9·35	4·00	13·10	139
135	11·37	6·02	11·08	140
160	12·20	6·85	19·25	139
183	12·95	7·60	9·50	140
280	15·60	10·25	6·85	142
351	17·00	11·65	5·45	141
		Mean	....	0·00140

Comparison Solution.—N/5 for chloride, N/100 for free hydrochloric acid mean $c = 0{\cdot}00170$.

$$k_b/\mathrm{K} = 2780.$$

Dimethyl-anthranilic Acid, 

Basic Constant.—The method of preparation was that given by Willstätter and Kahn.* The acid was purified by three crystallisations from ether, and formed long, transparent needles which melted at 70°. Its strength as an acid was sufficient to prevent titration of acetic acid by phenolphthalein in its presence, but it was not strong enough to be titrated itself by the use of that indicator, so that it was found necessary to use *o*-nitrophenol as indicator in the catalysis experiment.

Methyl Acetate Catalysis.—0·3300 gramme of dimethyl-anthranilic acid in 20 c.c. of N/10 hydrochloric acid.

$v = 10.$ A = 28·05.

t.	Titre.	x.	A − x.	c.
0	2·67	—	28·05	—
701	8·00	5·33	22·72	0·00131
942	9·65	6·98	21·07	132
1185	11·20	8·53	19·52	133
1365	12·25	9·58	18·47	133
2090	15·95	13·28	14·77	133
2380	17·20	14·53	13·52	133
2670	18·40	15·73	12·32	134
		Mean		0·00133

Comparison Solution.—N/10 for chloride, N/20 for free hydrochloric acid, mean c = 0·00141, hydrolysis in N/10 solution = 47·2 per cent.

$$k_b/\mathrm{K} = 23{\cdot}5.$$

Acid Constant.—Dimethyl-anthranilic acid crystallised so well from ether that an attempt was made to determine its strength as an acid by the conductivity, but with each recrystallisation the conductivity steadily diminished, until it was too near that of pure water to be of value. The last determination made with water of conductivity $1{\cdot}2 \times 10^{-6}$, in a cell with unplatinised electrodes, gave the following result.

v.	μ.	100 m.	k.
8	0·0649	0·0172	$3{\cdot}8 \times 10^{-8}$

That the acid dissociation constant was not negligibly small was shown by the action on indicators, and also by the conductivity of the sodium salt, which exhibited evidence of but a small amount of hydrolysis.

* *Loc cit.*

Conductivity of sodium salt of dimethyl-anthranilic acid.

v	32·0	1024·0
μ	67·4	80·8

This experiment showed, however, that, though there was hydrolysis, it was very slight. The diazo-acetic ester method for the estimation of hydrion was also tried with a N/10 solution of dimethyl-anthranilic acid, but no measurable amount of nitrogen was evolved in two hours. This is a conclusive proof that the acid is extremely weak.

Methyl Acetate Saponification.—The methyl acetate saponification method of Shields did not adapt itself well to the case of dimethyl-anthranilic acid, since the only indicators with which one could estimate the acetic acid were more or less affected by the dimethyl acid. As the best available, *o*-nitrophenol was used, but it was not very satisfactory.

The solution was made by dissolving 0·258 gramme of dimethyl-anthranilic acid in 25 c.c. of N/16 sodium hydroxide and addition of 25 c.c. of N/16 methyl acetate solution.

$v = 32.$

t.	Titre.	x.	kc.
0	12·50	—	—
149	11·90	0·60	0·000066
222	10·63	1·87	60
400	10·40	2·10	45
1380	8·80	4·70	51
		Mean	0·000055

The saponification constant for soda and methyl acetate is 10·5, so that

$$\frac{k_a}{K} = \frac{10{\cdot}5}{0{\cdot}000055} = 1{\cdot}9 \times 10^5.$$

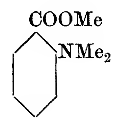
$$k_a = 1{\cdot}9 \times 10^5 \times 1{\cdot}2 \times 10^{-14} = 2{\cdot}3 \times 10^{-9}.$$

Physical Properties and Ring Formation.—It will be seen that there is a very marked drop in the acid dissociation constant when we introduce the second methyl group in the anthranilic series.

In the meta series, on the other hand, it was found that the mono- and di-methyl acids agreed closely in all their physical properties, such as solubility, appearance, and the acid and basic constants.

The following summary of the physical properties of dimethyl-anthranilic

acid, in comparison with the allied substances, leaves little doubt that the difference is stereochemical, and that this acid is more closely related to the betaines, possessing a tendency to ring formation, which would naturally be most marked in the ortho series. In the first place, dimethyl-anthranilic acid resembles in external appearance *o*-benzbetaine much more closely than it does anthranilic or monomethyl-anthranilic acid, since it forms soft, transparent crystals, which are characteristic of both ortho- and meta-benzbetaine. It dissolves also very readily in water and alcohol, and slightly in ether, thus agreeing with the betaines, but not with the other substances. The melting point of anthranilic acid is 144°; the mono derivative melts at 179°, whilst the dimethyl derivative melts at 70°. In the meta series the mono- and di-methyl derivatives melt within 4° of one another. The similarity to the betaine suggests ring formation in the molecule, and this would at once explain the low acid dissociation constant, since extensive ring formation and pronounced acid properties are incompatible.

Methyl Ester of Dimethyl-anthranilic Acid, 

Basic Constant.—This ester was prepared by the method of Willstätter and Kahn, purified by distillation, and its strength as a base determined by a methyl acetate catalysis with the hydrochloride. The hydrochloride was prepared by passing hydrogen chloride through an ethereal solution of the ester, when the salt separated as a white crystalline solid, which was purified by several washings with ether.

The hydrochloride of the methyl ester of dimethyl-anthranilic acid, which has not been previously described, melts with decomposition at 145° to 147°, is very soluble in water, soluble in alcohol, insoluble in ether, and is slightly deliquescent. Its identity was confirmed by analysis of the amount of chlorine.

0·1925 gramme of the hydrochloride contained 0·0297 gramme of the chlorine.

Chlorine found	....	16·40 per cent.
Calculated for $C_{10}H_{14}O_2NCl$	....	16·45 ,,

Methyl Acetate Catalysis.—0·862 gramme of the hydrochloride of the methyl ester of dimethyl-anthranilic acid was dissolved in 20 c.c. of water.

$v = 5.$ $A = 28{\cdot}18.$

t.	Titre.	x.	$A-x$.	c.
0	5·30	—	28·18	—
89·5	11·37	6·07	22·11	0·000118
114	13·30	8·00	20·18	128
118	13·60	8·30	19·88	128
138	16·75	11·45	16·73	140
143	17·15	11·85	16·33	142
			Mean	0·000131

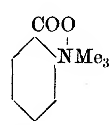
Comparison Solution.—N/5 for chloride, N/200 for free hydrochloric acid, mean $c = 0{\cdot}0000880$.

$$k_b/\mathrm{K} = 3500.$$

It will be seen that c is here only approximately a constant, as it showed a steady increase with time. It was found by repetition of the experiment that this was a real variation and not due to experimental error. In another set of experiments, in which the readings were taken at an earlier stage of the reaction, the value obtained for k_b/K was somewhat higher, viz., 4200. The explanation is, doubtless, that the methyl ester of dimethyl-anthranilic acid undergoes slight hydrolysis (saponification) itself during the course of the reaction, and the hydrolysis of any of this ester involves the liberation of an equivalent quantity of hydrochloric acid, since at such a great dilution any hydrochloride of dimethyl-anthranilic acid would be almost completely hydrolysed. The influence of such a secondary action would be very small if the ester hydrochloride were much hydrolysed, but when we are dealing with a comparatively strong base, such as we have here, the effect on the apparent k_b/K is at its maximum.

As an instance, we may consider an ester whose real k_b/K is 7800, and suppose that in N/5 solution the ester is itself hydrolysed 1 per cent. before the readings are taken; the apparent k_b/K will then be 3100.

The k_b/K for the methyl ester of dimethyl-anthranilic acid may, therefore, be taken as not below 4000, and from a consideration of the rate at which the constant falls off with time, it is probable that the real k_b/K lies between 5000 and 6000.

o-Benzbetaine,  .

Basic Constant.—*o*-benzbetaine, prepared by the method of Willstätter and Kahn, was repeatedly crystallised from alcohol, and in this manner obtained in large transparent crystals, which melted at 225°. The basic dissociation

constant was found by a methyl acetate catalysis with a solution of the hydrochloride prepared from the pure betaine and an equivalent quantity of hydrochloric acid.

Methyl Acetate Catalysis.—0·3760 gramme of *o*-benzbetaine in 20 c.c. of N/10 hydrochloric acid.

$v = 10.$ $A = 17 \cdot 00.$

t.	Titre.	*x*.	A−*x*.	*c*.
0	2·60	—	17·00	—
488	4·95	2·35	14·65	0·000132
790	6·30	3·70	13·30	135
1430	8·57	5·97	11·03	132
1799	9·90	7·30	9·70	135
2020	10·48	7·88	9·12	134
2160	10·95	8·35	8·65	135
2990	12·80	10·20	6·80	133
		Mean	....	0·000134

Comparison Solution.—N/10 for chlorides, 0·07 N for free hydrochloric acid, mean $c = 0 \cdot 000199$, hydrolysis of *o*-benzbetaine hydrochloride in N/10 solution = 47 per cent.

$$k_b/K = 23 \cdot 2.$$

Acid Constant.—*o*-benzbetaine, which had been several times crystallised from alcohol, was found to possess an appreciable conductivity, but further careful crystallisation produced a steady lowering, until the last conductivity obtained from a N/16 solution was only three times that of pure water.

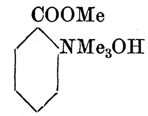
The method of Shields was therefore used, and, as a preliminary experiment showed the hydrolysis to be very large, a solution of pure caustic soda was employed as a comparison:—

(A) 0·295 gramme of *o*-benzbetaine was dissolved in 25 c.c. of N/16 sodium hydroxide and diluted to 100 c.c. This was mixed with 100 c.c. of of N/64 methyl acetate, so that the final dilution of all constituents was 128.

(B) 100 c.c. N/64 sodium hydroxide solution was mixed with 100 c.c. of N/64 methyl acetate, and *v* was here also 128.

t.	Pure NaOH.	NaOH with *o*-benzbetaine.
0	15·50	15·50
8	8·85	—
11	—	7·55
20	5·25	5·20
37	3·35	3·35

It is evident that all the caustic soda is free, and the conclusion is, therefore, that *o*-benzbetaine possesses no measurable acid properties.

The Hydroxide of the Methyl Ester of o-Benzbetaine, 

Willstätter and Kahn have shown that if an aqueous solution of the methiodide of the methyl ester of dimethyl-anthranilic acid is acted on by silver oxide at zero, a strong base is obtained, which quickly disappears, and the solution is found to contain only the *o*-benzbetaine. The base is undoubtedly the hydroxide of the methyl ester of *o*-benzbetaine, and the methiodide the iodide of the same base. This iodide is quite stable in aqueous solution and it was, therefore, prepared and purified by two crystallisations from water. It melted at 153°, and analysis for iodine gave the following result:—

0·3165 gramme of the iodide contained 0·1234 gramme of iodine.

Iodine found.............................	39·0	per cent.
Calculated for $C_{11}H_{16}O_2NI$	39·46	„

Basic Strength of the Hydroxide.—An attempt was made to find the extent of hydrolysis of the iodide in N/5 solution by catalysis of methyl acetate, but it was too small to detect in this manner.

By the delicate method of Bredig and Fraenkel extremely minute concentrations of hydrion can be readily recognised, but a N/50 solution of the iodide of the methyl ester of *o*-benzbetaine, when mixed with diazo-acetic ester in the usual manner, caused no evolution of nitrogen at all. This proved conclusively that there was no appreciable hydrolysis.

Autosaponification of the Hydroxide of the Methyl Ester of o-Benzbetaine.—An ice-cold solution of the methiodide of *o*-benzbetaine,

$$C_6H_4.N(CH_3)_3I.COOCH_3,$$

was mixed with a measured volume of ice-cold water in which excess of freshly prepared and thoroughly washed silver oxide was suspended.

After shaking for two or three minutes, the solution was filtered off from the silver oxide and iodide. If the temperature was kept very near zero throughout, an almost quantitative yield of the tetramethyl derivative was obtained, provided that the solutions were very dilute.

The hydroxide of the methyl ester of *o*-benzbetaine is a substance of peculiar interest, since it is at the same time a strong base and an ester. The experiments with its iodide showed the base to be a very strong one, and it was found that even in very dilute solution it quickly decomposed. Since the end products were neutral, this reaction could be readily followed by

titration, and it was conclusively proved that the decomposition was due to the saponification of the ester part of the molecule by the hydroxidion which the same substance formed in virtue of its property as a base.

Rate of Decomposition.—100 c.c. of N/50 tetramethyl iodide solution was shaken with 100 c.c. of water containing excess of silver oxide, and immediately filtered. Precautions were taken to keep the temperature as near 0° as possible, and the solution after filtration was kept in a vessel surrounded by finely crushed ice. The solution was found by the first titration to be 0·00995 N.

t.	Titre.	x.	c.	k.
0	9·95	—	—	—
14	9·50	0·45	0·00159	0·329
31	8·95	1·00	0·00156	0·278
103	7·50	2·45	0·00121	0·317
163	6·82	3·13	0·00102	0·282
273	5·26	4·69	0·00086	0·321
			Mean	0·31

c should be a constant if the action were monomolecular, whilst if we take the action as bimolecular we should get

$$k = \frac{1}{\mathrm{A}t} \cdot \frac{x}{(\mathrm{A}-x)},$$

where A is the total change expressed in terms of a normal solution, and x is the amount changed in any time t.

The reaction is evidently bimolecular, as it should be if it were an action between an ester and the hydroxidion produced by the electrolytic dissociation of the basic group.

Rate of Decomposition in Presence of Sodium Hydroxide.—To obtain a comparison between the strength of the base and that of sodium hydroxide, a similar experiment was performed under identical conditions, except that the solution was made not only N/100 for the ester-base, but also N/100 for sodium hydroxide.

t.	Titre.	x.	k.
0	19·65	—	—
10	18·92	0·73	0·848
42	17·40	2·25	0·744
104	15·45	4·20	0·768
145	14·40	5·25	0·853
177	13·80	5·85	0·902
		Mean	0·82

The constant k is calculated as before from the equation—

$$k = \frac{1}{\mathrm{A}t} \cdot \frac{x}{\mathrm{A}-x}.$$

From this it appears that the rate at which the ester-base saponified itself is roughly half that at which the saponification occurred when an equivalent amount of sodium hydroxide was also present. Strictly the above equation should have been replaced by one taking account of the two reactions.

$$\frac{d\,(x+y)}{dt} = k_1\,(\mathrm{A}-x)^2 + k_2\,(\mathrm{A}-y)\,(\mathrm{A}-x),$$

where A is the original concentration of the ester-base and also of the sodium hydroxide, and x and y the amounts hydrolysed by the ester-base and the sodium hydroxide respectively in any time t. The data are not sufficiently accurate to test this equation, but the evidence supports the assumption that x and y are approximately equal, *i.e.*, that the ester-base supplies as much hydroxidion as the sodium hydroxide.

Rate of Decomposition in Presence of Methyl Acetate.—Perhaps the most convincing proof that the hydroxide of the methyl ester of *o*-benzbetaine is really a strong base, and yields hydroxidion, was afforded by its action on methyl acetate. A solution of the ester-base was prepared from the iodide with silver oxide, and sufficient methyl acetate solution added to make the mixed solution 0·01 N for both constituents. The solution was at once filtered, and titrated at intervals, being kept at zero as in the previous experiments.

t.	Titre.	x.
0	8·30	—
10	6·63	1·67
20	5·78	2·52
36	4·65	3·65
71	3·20	5·10
97	2·55	5·75
1100	0·10	8·20

The equilibrium in the above solution is so complex that no attempt has been made to calculate the constant for the reaction, but a comparison of these figures with those given for the auto-saponification of the ester-base at the same temperature and dilution show that the methyl acetate was rapidly saponified by the ester-base, which thus possesses basic properties comparable with those of sodium hydroxide.

Conductivity of the Hydroxide of the Methyl Ester of o-Benzbetaine.—The conductivity of the tetramethyl derivative in comparison with that of

sodium hydroxide is of some interest. The constant of the cell was determined at 1°, and measurements were then made at about that temperature with N/60 sodium hydroxide and N/60 hydroxide of the methyl ester of *o*-benzbetaine, under conditions as nearly identical as possible. The N/60 hydroxide of the methyl ester of *o*-benzbetaine was prepared from its iodide by interaction with thoroughly washed silver hydroxide, and filtered at once into the measuring vessel. From the amount of iodide used and the volume, the strength of the solution should have been 0·0167 N. From a titration made immediately after the filtration, it was found to be 0·0163 N.

Conductivity of the Hydroxide of the Methyl Ester of *o*-Benzbetaine.

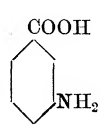
Time after filling vessel.	Temp.	v.	λ.
3	1°·2	60	0·134
8	0·7	60	0·123

Conductivity of Sodium Hydroxide under the same Conditions.

Time after filling vessel.	Temp.	v.	λ.
10	1°·1	60	0·147
15	0·8	60	0·133

The agreement is sufficiently close to show that the dissociation and ionic velocities must be of the same order of magnitude.

It may be remarked that it would be possible to follow the self-saponification of the ester-base by means of the conductivity, since the ester-base is a strong electrolyte, while the products *o*-benzbetaine and methyl alcohol are non-electrolytes. In the above experiment the conductivity fell about 1/6 in one hour.

m-Aminobenzoic Acid, 

Hydrion Concentration.—The diazo-acetic ester method for the estimation of hydrion was tried at various dilutions.

The constants for acetic and benzoic acids have already been given under anthranilic acid. If benzoic acid be taken as the standard, the hydrion concentration in N/64 *m*-aminobenzoic acid is 28×10^{-5}. With acetic acid as standard it is 22×10^{-5}. Walker's calculated value is $11{\cdot}8 \times 10^{-5}$, while that of a simple acid with a conductivity equal to that of *m*-aminobenzoic acid would be $40{\cdot}8 \times 10^{-5}$.

$v = 64.$

t.	Reading.	*x*.	A − *x*.	*c*.
0	1 ·75	—	22 ·20	—
33	6 ·28	4 ·53	17 ·67	0 ·00301
44	7 ·60	5 ·85	16 ·35	293
62	9 ·55	7 ·80	14 ·40	303
91	12 ·10	10 ·35	11 ·85	299
123	14 ·37	12 ·62	9 ·50	300
132	15 ·13	13 ·38	8 ·82	304
			Mean	0 ·00300

$v = 64.$

t.	Reading.	*x*.	A − *x*.	*c*.
0	1 ·60	—	22 ·40	—
35	6 ·70	5 ·10	17 ·30	0 ·00320
40	7 ·25	5 ·65	16 ·75	315
50	8 ·50	6 ·90	15 ·50	320
60	9 ·55	7 ·95	14 ·45	317
80	11 ·37	9 ·77	12 ·63	311
90	12 ·32	10 ·72	11 ·68	314
100	13 ·18	11 ·58	10 ·82	316
			Mean	0 ·00316

$v = 256.$

t.	Reading.	*x*.	A − *x*.	*c*.
0	2 ·70	—	22 ·40	—
30	6 ·08	3 ·38	19 ·02	0 ·00236
40	7 ·00	4 ·30	18 ·10	231
50	8 ·00	5 ·30	17 ·10	232
63	9 ·07	6 ·37	16 ·03	231
84	10 ·78	8 ·08	14 ·32	231
103	12 ·10	9 ·40	13 ·00	230
			Mean	0 ·00232

$v = 512.$

t.	Reading.	*x.*	A − *x.*	*c.*
0	1·50	—	24·50	—
33	5·50	4·00	20·50	0·00235
46	7·15	5·65	18·85	247
61	8·70	7·20	17·30	242
87	10·57	9·07	15·43	236
110	12·50	11·00	13·50	235
121	13·23	11·73	12·87	231
			Mean	0·00238

$v = 1024.$

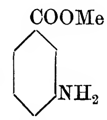
t.	Reading.	*x.*	A − *x.*	*c.*
0	3·20	—	22·40	—
70	8·70	5·50	16·90	0·00174
107	10·95	7·75	14·65	173
140	12·90	9·70	12·70	176
176	14·57	11·37	11·03	175
203	15·70	12·50	9·90	175
269	17·83	14·63	7·77	171
			Mean	0·00174

There are several causes which may contribute to the discrepancy between the calculated and the observed value, for instance, the influence of ionised salt on the diazo-acetic ester. According to Walker's theory there must be ionised salt present, since *m*-aminobenzoic acid possesses marked acid and basic properties. Further, we have no positive knowledge of the effect of unionised molecules, or of the addition of alcohol to an aqueous solution of an amphoteric electrolyte.

There is, however, a method of comparison which is open to less uncertainty, namely, to ascertain the effect of dilution on the hydrion concentration. In this case the influence of disturbing factors should be regular throughout.

It was found by experiment that the hydrion concentration of N/64 benzoic acid was roughly double that of a N/256 solution, as should be the case with a simple acid, according to Ostwald's dilution law. The divergence of an amphoteric electrolyte from the simple law is clearly shown in the following table, in which the hydrion concentration with $v = 64$ has been called 100, the figures for the other dilutions being calculated on this basis:—

v	64.	128.	256.	512.	1024.
Experimental for m-amino-benzoic acid	100	—	75·3	77·1	56·5
Calculated from Walker's paper	100	96·7	91·0	82·2	69·8
Calculated for a simple acid	100	71	50	35	25

Methyl Ester of m-Aminobenzoic Acid, 

Basic Constant.—The strength of this ester as a base was found by a methyl acetate catalysis with the hydrochloride, the preparation of which has already been described.

Methyl Acetate Catalysis.—1·870 grammes of the hydrochloride of the methyl ester of m-aminobenzoic acid were dissolved in 20 c.c. of water.

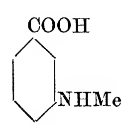
$$v = 2. \qquad A = 16{\cdot}20.$$

t.	Titre.	x.	A $-$ x.	c.
0	13·70	—	16·20	—
370	16·65	2·95	13·25	0·000236
583	18·13	4·43	11·77	237
1070	20·88	7·18	9·02	237
1320	21·95	8·25	7·95	234
1550	22·93	9·23	6·97	236
		Mean		0·000236

Comparison Solutions.—(1) N/2 for chloride, N/100 for free hydrochloric acid; mean c = 0·000202.

(2) N/2 for chloride, N/66·7 for free hydrochloric acid; mean c = 0·000306.

$$k_b/K = 3600.$$

Monomethyl m-Aminobenzoic Acid, 

Basic Constant.—Whenever possible it is preferable to use a crystalline salt in making up a solution for hydrolysis purposes and, accordingly, a methyl acetate catalysis was performed with the thrice crystallised hydriodide of monomethyl m-aminobenzoic acid, the preparation and analysis of which will be found in the first part of this paper.

Methyl Acetate Catalysis.—0·585 gramme of the hydriodide of monomethyl *m*-aminobenzoic acid in 20 c.c. of water. $v = 10$.

t.	Titre.	*x.*	A − *x.*	*c.*
0	3·97	—	12·85	—
1103	7·30	3·33	9·52	0·000119
1350	7·97	4·00	8·85	120
1435	8·16	4·19	8·66	119
1593	8·50	4·53	8·32	119
1680	8·73	4·76	8·09	120
			Mean	0·000119

Comparison Solution.—N/10 for chloride, N/200 for free hydrochloric acid, mean $c = 0·000843$, hydrolysis in N/10 solution = 7·1 per cent.

$$k_b/\mathrm{K} = 1580.$$

These results appeared to fix the basic strength of monomethyl *m*-aminobenzoic acid with fair certainty, but when it was found that an iodide is liable to give too high a result, the chloride was tried.

It was not found possible to obtain the chloride in a pure crystalline state, so hydrochloric acid was added to weighed quantities of monomethyl *m*-aminobenzoic acid. The first two experiments gave the hydrolysis in N/10 solution as 16 per cent. and 15·2 per cent. respectively, which would mean that the k_b/K was about 350, as against 1850 from the experiment with the iodide. There seemed a possibility that the acid had oxidised in the chloride experiments, and an experiment was therefore performed in a flask from which the air was expelled after each titration with nitrogen. The result was as follows:—

Methyl Acetate Catalysis.—0·302 gramme of monomethyl *m*-aminobenzoic acid in 20 c.c. of N/10 hydrochloric acid. $v = 10$.

t.	Titre.	*x.*	A − *x.*	*c.*
0	4·70	—	25·20	—
452	9·18	4·48	20·72	0·000184
677	10·98	6·28	18·92	183
740	11·50	6·80	18·40	185
931	13·00	8·30	16·90	186
			Mean	0·000184

Comparison Solution.—N/10 for chloride, N/100 for free hydrochloric acid, mean $c = 0·000182$, hydrolysis in N/10 solution = 10·1 per cent.

$$k_b/\mathrm{K} = 900.$$

The difference between the values obtained from the chloride and iodide is still large, and there seems no means of determining the exact value. As that from the chloride is probably too low, and the iodide value too high, k_b/K has been taken as 1000 in the calculation of the acid constant from the conductivity.

Conductivity and Acid Constant.—Though monomethyl *m*-aminobenzoic acid was repeatedly crystallised, it was not found possible to obtain it quite free from colour, but the sample used for the conductivity was almost colourless.

Conductivity of the Sodium Salt.—

$$v = 32, \mu = 69{\cdot}9. \qquad v = 1024, \mu = 79{\cdot}7.$$

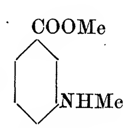
μ_∞ was taken as 81, and μ_∞ for the monomethyl *m*-aminobenzoic acid as 377.

$\mu'_\infty = 66$, so that $\alpha = a + 66/377d$.

Conductivity of Monomethyl m-Aminobenzoic Acid.—The water used had a conductivity of $0{\cdot}9 \times 10^{-6}$. The solutions were made in glass vessels, which were known not to alter the conductivity. $k_b/K = 1000$.

v.	μ experiment.	μ calculated for $k_a = 0{\cdot}8 \times 10^{-5}$.	$k_0 \times 10^{-5}$ experiment.	k_0 calculated for $k_a = 0{\cdot}8 \times 10^{-5}$.
82	7·47	7·51	0·488	0·493
164	9·90	9·66	0·430	0·411
328	14·0	13·6	0·436	0·414
656	21·1	20·3	0·506	0·467
1312	32·1	31·7	0·665	0·575
1312	31·6		0·586	

In view of the uncertainty as to the exact value of k_b/K, the agreement between the experimental and calculated values of the molecular conductivity μ may be regarded as satisfactory.

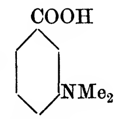
Methyl Ester of Monomethyl m-Aminobenzoic Acid, 

Although both the ester and its hydrochloride were prepared, no value can be given for the basic constant of this ester on account of its extreme insolubility. On addition of water to the hydrochloride, the hydrochloric acid all dissolves, but none of the ester.

The Löwenherz solubility method was tried, but a litre of N/2 hydrochloric acid only dissolved a few milligrammes of the ester. Farmer's*

* Farmer and Warth, 'Chem. Soc. Journ.,' vol. 85, p. 1713, 1904.

method was also tried, using benzene as the non-aqueous solvent, but the whole of the ester dissolved in the benzene and none in the water.

Dimethyl m-Aminobenzoic Acid, 

Basic Constant.—The specimen used for the physical determinations was prepared from *m*-benzbetaine,* and crystallised once from alcohol and twice from water. The strength as a base was found by catalysis of methyl acetate.

Methyl Acetate Catalysis.—0·1650 gramme of dimethyl *m*-aminobenzoic acid was dissolved in 10 c.c. of N/10 hydrochloric acid, and 5 c.c. of water. $v = 15$, $A = 15·75$.

t.	Titre.	*x.*	A − *x.*	*c.*
0	2·68	—	15·75	—
508	4·45	1·77	13·98	0·0000102
743	5·28	2·60	13·15	106
1870	8·57	5·89	9·86	109
2350	9·70	7·02	8·73	109
			Mean	0·0000106

Comparison Solution.—N/15 for chloride, N/150 for free hydrochloric acid, $c = 0·0000115$.

$$k_b/K = 1630.$$

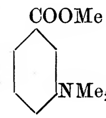
A repetition of this determination with a sample of dimethyl acid prepared by the new method gave $k_b/K = 1580$, the experiment being performed in N/10 solution in the same manner as the above.

Acid Constant.—The preparation of this substance has already been described. The sample used was several times crystallised from water. The conductivity of the sodium salt at $v = 1024$ was 77·5, and the figures used for μ_∞ and μ'_∞ were, therefore, $(79+296) = 375$, and $(375-347) \times 2+6 = 62$ respectively. The value of k_b/K used in the calculations was 1580. The water used had a conductivity of $1·2 \times 10^{-6}$.

v.	μ experiment.	k_0 experiment.	k_0 calculated for $k_a = 0·8 \times 10^{-5}$.
128	8·55	0·415	0·43
256	11·9	0·405	0·40
512	17·4	0·44	0·39
1024	26·9	0·54	0·45
1024	27·0	0·55	0·45

* Griess, *loc. cit.*

The reason for the discrepancy in this case between the theoretical and experimental numbers is not apparent. It is probably connected with the high value of k_b/K.

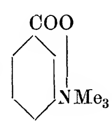
Methyl Ester of Dimethyl m-Aminobenzoic Acid, 

Methyl Acetate Catalysis.—0·864 gramme of the hydrochloride of the methyl ester of dimethyl *m*-aminobenzoic acid was dissolved in 25 c.c. of water. $v = 6{\cdot}25$, $\mathrm{A} = 22{\cdot}50$.

t.	Titre.	*x.*	A − *x.*	*c.*
0	4·00	—	22·50	—
76	7·35	3·35	19·15	0·00092
119	9·06	5·06	17·44	93
168	10·92	6·92	15·58	95
190	11·82	7·82	14·68	97
			Mean	0·00094

Comparison Solution.—N/6 for chloride, 0·006 N for free hydrochloric acid, $c = 0{\cdot}000111$; the constants were 0·000110, 111, 112, 112.

$$k_b/\mathrm{K} = 6000.$$

m-Benzbetaine,  .

Basic Constant.—*m*-Benzbetaine is deliquescent and the hydrochloride was therefore prepared for the methyl acetate catalysis, which was performed also with the hydriodide.

Methyl Acetate Catalysis.—0·861 gramme of the hydrochloride of *m*-benzbetaine in 20 c.c. of water. $v = 5$, $\mathrm{A} = 16{\cdot}20$.

t.	Titre.	*x.*	A − *x.*	*c.*
0	2·65	—	16·20	—
71·5	6·20	3·55	12·65	0·00151
76·2	6·51	3·86	12·34	155
92·5	7·25	4·60	11·60	157
97·0	7·40	4·75	11·45	155
139	9·14	6·49	9·71	160
			Mean	0·00156

Comparison Solution.—N/5 for chlorides, N/100 for free hydrochloric acid, mean $c = 0{\cdot}00188$, hydrolysis of betaine hydrochloride in N/5 solution = 4·14 per cent.

$$k_b/\mathrm{K} = 2800.$$

A similar experiment with *m*-benzbetaine hydriodide showed it to be 3·96 per cent. hydrolysed, or with a k_b/K of 3060. Probably the lower value is the more correct, as it has already been mentioned that iodides show less than the true amount of hydrolysis.

Acid Constant.—*m*-Benzbetaine crystallised from alcohol, but on account of its great solubility and deliquescence it was not found possible to reduce the conductivity to a minimum, as it continued to fall with each recrystallisation.

Saponification of methyl acetate, in the same manner as described under *o*-benzbetaine, was performed with three solutions which were all N/128 for sodium hydroxide, but contained respectively no betaine, one equivalent of betaine, and two equivalents of the betaine. The results are given in this table:—

t.	Pure NaOH N/128.	N/128 NaOH and N/128 *m*-benzbetaine.	N/128 NaOH and N/64 *m*-benzbetaine.
0	15·50	15·50	15·50
8	8·85	8·70	8·20
15	6·35	6·35	6·30
20	5·25	5·40	5·05

It is evident that *m*-benzbetaine, like the similar ortho compound, is practically devoid of acid properties.

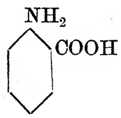
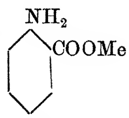
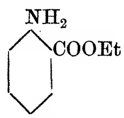
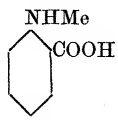
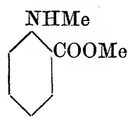
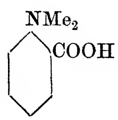
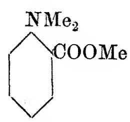
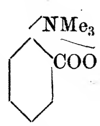
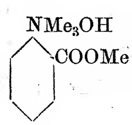
The Hydroxide of the Methyl Ester of m-Benzbetaine.

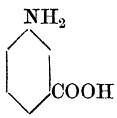
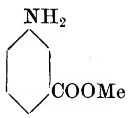
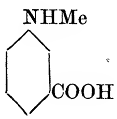
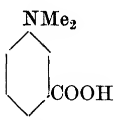
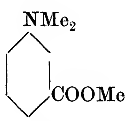
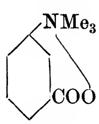
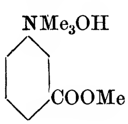
Basic Strength.—The iodide of this base was faintly acid to azolitmin, but neutral to other indicators. No hydrolysis could, however, be detected in N/64 solution with diazo-acetic ether, and the base was evidently very strong.

Addition of moist silver oxide to a cold solution of the iodide gave a strongly alkaline solution which became neutral in a few minutes.

This hydroxide, like the corresponding ortho compound, has a basic constant of the same order of magnitude as caustic soda.

Summary of Results.

	k_a.	k_a/K.	k_b.	k_b/K.
	$1 \cdot 04 \times 10^{-5}$	$8 \cdot 6 \times 10^{8}$	$1 \cdot 3 \times 10^{-12}$	110
	—	—	$1 \cdot 7 \times 10^{-12}$	143
	—	—	$1 \cdot 5 \times 10^{-12}$	126
	$0 \cdot 46 \times 10^{-5}$	$3 \cdot 8 \times 10^{8}$	$0 \cdot 94 \times 10^{-12}$	77
	—	—	$33 \cdot 6 \times 10^{-12}$	2780
	$0 \cdot 00023 \times 10^{-5}$	$1 \cdot 9 \times 10^{5}$	$0 \cdot 28 \times 10^{-12}$	23 ·5
	—	—	$60 \cdot 5 \times 10^{-12}$	5000
	$< 10^{-14}$	< 1	$0 \cdot 28 \times 10^{-12}$	23 ·2
	—	—	Very great	Very great

	k_a.	k_a/K.	k_b.	k_b/K.
	$1 \cdot 63 \times 10^{-5}$	$13 \cdot 5 \times 10^{8}$	$13 \cdot 3 \times 10^{-12}$	1110
	—	—	$43 \cdot 6 \times 10^{-12}$	3600
	$0 \cdot 8 \times 10^{-5}$	$6 \cdot 6 \times 10^{8}$	*ca.* 12×10^{-12}	*ca.* 1000
	$0 \cdot 8 \times 10^{-5}$	$6 \cdot 6 \times 10^{8}$	$19 \cdot 4 \times 10^{-12}$	1600
	—	—	73×10^{-12}	6000
	$< 10^{-14}$	< 1	34×10^{-12}	2800
	—	—	Very great	Very great